Beam Halo Measurements using Wire Scanners at ATF2

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BEAM HALO MEASUREMENTS USING WIRE SCANNERS AT ATF2*

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Abstract

Beam halo hitting on the beam pipe after the Interaction Point (IP) can generate a large amount of background for the measurements of the nano meter beam size using the laser interferometer beam size monitor (Shintake monitor) at ATF2. In order to investigate the beam halo transverse distribution, a diamond detector will be installed downstream of the IP. A feasibility study of a transverse halo collimation system to reduce the background for these measurements is also in progress. Prior to the diamond detector installation, a first attempt of beam halo measurements have been performed in 2013 using the currently installed wire scanners. Modeling of the beam halo distribution in the extraction (EXT) line was done and compared with the old modeling for ATF. Beam halo measurements were also done using the post-IP wire scanner to investigate the beam halo distribution at post-IP.

INTRODUCTION

ATF2 is a scaled down prototype of the final focus system of future linear colliders (ILC and CLIC). One of the two goals of ATF2 is to measure 37 nm beam size using the Shintake-monitor. This monitor utilize the laser interference fringe to scan the beam and measure the beam size according to the modulation of the signal of the Compton scattered photons detected by a photon detector downstream [1]. This measurement is severely sensitive to the background photons. The main background source are the photons generated by the beam halo hitting on the beam pipe of the BDUMP bending magnet. Therefore, it is of great importance to understand the beam halo distribution and to control the background generated by the beam halo.

First beam halo measurements were done in 2005 using the five wire scanners located in the old EXT line of ATF, these measurements provide us the first information about beam halo distribution in the EXT line [2]. Parametrizations were done for the horizontal and vertical beam halo distribution according to these measurements.

At present, the EXT line of ATF2 differs from the old one, new measurements using the wire scanners are required to update the beam halo model, which can be used for the feasibility study of a collimation system for ATF2 [3]. Therefore, the main objective of this work is to perform beam halo measurements using the wire scanners of the EXT line, obtain a beam halo model for the new ATF2 beam line and compare it with the old model. Furthermore, measurements have been done using the post-IP wire scanners to investigate the beam halo distribution at post-IP. These measurements are useful both for the understanding of backgrounds in the Shintake monitor and for the understanding of beam halo collimation requirements.

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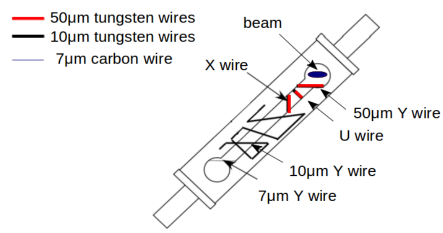
WIRE SCANNERS AT ATF2

At ATF2 the wire scanners are used to measure the beam size at different locations. The beam is scanned by the wire and the photons generated by bremsstrahlung are detected by the photon detectors installed downstream.



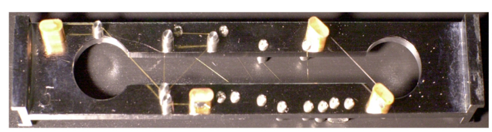


Figure 1: Structure of wire scanner. The total length of wire scanner is around 150mm and the distance between two wire centers is 10mm.

Figure 1 shows the structure of the wire scanners. The wire scanners are installed with an angle of 45° to the beam line to enable the simultaneous scan in 3 axes [4]. The X and Y wires are used for horizontal and vertical scan. The U wire, which is 45° to X and Y wire is used to measure the correlation between horizontal and vertical measurements. In addition, two 10 μm tungsten wires with +10° and -10° tilted from X direction are used to measure the tilt angle of the beam profile. As the resolution of the beam size measurement depends on the wire diameter, three Y wires with different diameters (7 μm, 10 μm and 50 μm) were installed in the wire scanner to measure different vertical beam sizes [5].

In our experiments we have used the MW2X, MW3X and post-IP wire scanners. MW2X and MW3X are located in the EXT line. A Cherenkov detector at around 26 m downstream of MW2X and 22m downstream of MW3X is used to detect the bremsstrahlung photons generated by the wire. For the measurements in the EXT line, where the vertical beam size is relatively small, we used the 50 μm tungsten X wire for horizontal scan and the 10 μm tungsten Y wire for vertical scan. The post-IP

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wire scanner is located at 75 cm downstream of the IP. It uses a plastic scintillation detector at the same location as the photon detector used for the Shitake-monitor. For the measurements at post-IP, we used 50 µm tungsten X and Y wire for horizontal and vertical scan.

The wire scanners were designed for doing beam size measurement and 8 wires are arranged next to each other. This fact could limit this device for beam halo measurements, because the measurements using one wire could be affected by the background noise generated by the interaction of beam halo with the other surrounding wires. Moreover, the dynamic range of the measurement is limited by the gain of the photomultiplier (PMT) and the 14 bit ADC used for the photon detectors. Therefore, in order to get better resolution for the beam halo measurement, we first applied lower voltage to PMT to measure the beam core and then the voltage is increased step by step to scan the beam halo. The signal strength measured by the photon detectors is corrected by the total beam charge measured by the Integrated Current Transformers (ICT) to take into account the fluctuation of beam intensity. Furthermore, the data taken at higher voltages is normalized according to the overlap region with the data taken at lower voltages.

BEAM HALO MEASUREMENT IN THE EXT LINE

Data taken in 2005 using the five wire scanners in the old EXT line have shown that the distribution of halo depends on number of σ rather than absolute distance from the beam center. If the total number of electrons is N, the density of the horizontal beam halo (ρ_h) and vertical beam halo (ρ_v) as a function of number of σ is given by:

$$\rho_h = 0.22 * N * x^{-3.5} \qquad (>3\sigma)$$

$$\rho_v = \begin{cases} 0.22 * N * x^{-3.5} & (3\sigma \text{ to } 6\sigma) \\ 0.037 * N * x^{-2.5} & (>6\sigma) \end{cases}$$

where x is the number of σ and N in this case is 10^{10} electrons.

As the new EXT line at ATF2 is different from the old EXT line, new measurements have been done for the present beam line. Three series of measurements were done in April, June and December 2013, only part of the results are shown in this paper. Figure 2 shows the horizontal and vertical beam halo measurements done in April 2013. The beam core (< 3σ) is fitted by a Gaussian distribution.

Figure 3 shows the fit for the beam halo distribution from 3σ to 6σ, beam halo beyond 6σ is covered by the background. The fit of these measurements gives a beam halo density as a function of σ given by:

$$\rho_h = 9.04 * N * x^{-6.8} \qquad (3\sigma \text{ to } 6\sigma)$$

$$\rho_v = 12.00 * N * x^{-6.8} \qquad (3\sigma \text{ to } 6\sigma)$$

where N in these experiments is 10^9 electrons.

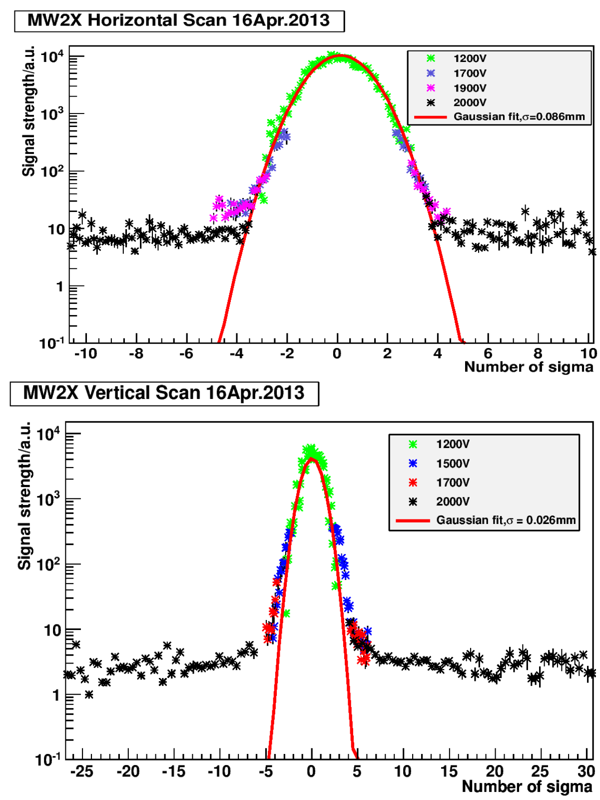

Figure 2: Horizontal (top) and vertical (bottom) beam halo distribution measured by MW2X.

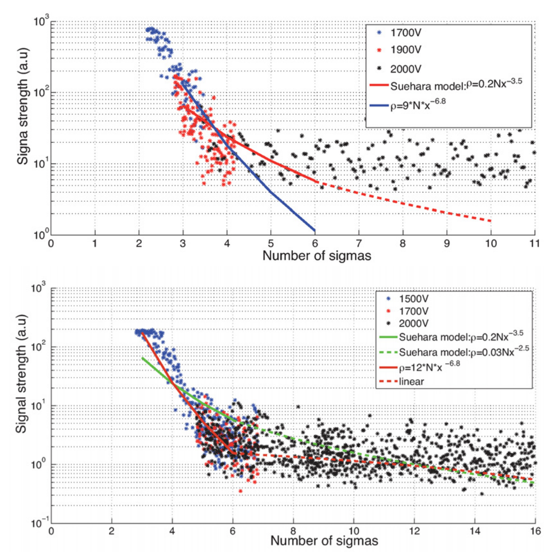

Figure 3: Fit of horizontal (top) and vertical (bottom) beam halo.

BEAM HALO MEASUREMENT AT POST-IP

Similar study has been performed using the post-IP wire scanner. The 50 µm tungsten Y wire was used for the vertical scan. The range scan for the Y wire is larger than for the other wires because is the first wire which go through the beam during the scan and it has only one wire next to it (on the right side). Therefore, the background expected due to this fact is smaller than for the other wires and we could measure the beam halo up to 15σ_y on the left side and up to 10σ_y on the right side.

Figure 4 shows the normalized vertical beam halo distribution measured in June 2013 and the fit for the beam halo on the right side. The fit gives a beam halo density as a function of σ given by :

$$\rho_v = \begin{cases} 0.67 * N * x^{-2.2} & (3\sigma \text{ to } 6\sigma) \\ 0.11 * N * x^{-1.2} & (>6\sigma) \end{cases}$$

where N in this experiment is 10^9 electrons.

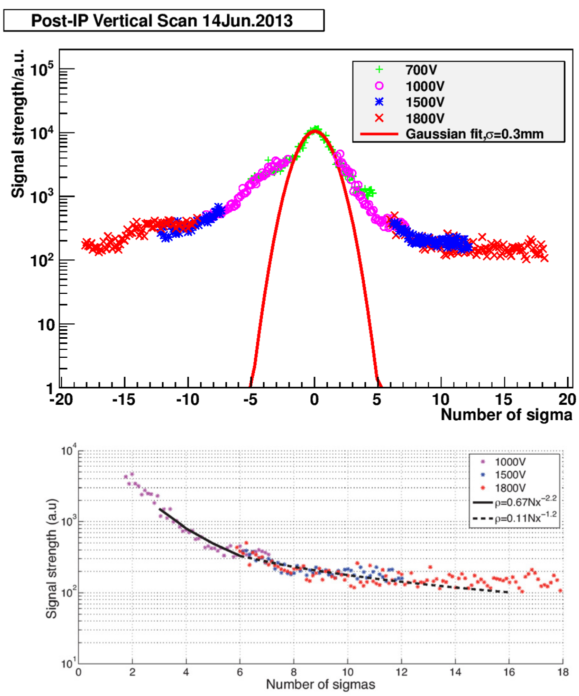

Figure 4: Distribution of beam halo measured by Post-IP wire scanner in June 2013 (top) and fit for the right side distribution (bottom).

We can see an edge of cut at around -15σ_y position, similar edge was also observed in the data taken in April 2013 [6]. This cut could be given by the tapered beam pipe (TBP) installed at 28m upstream of the IP between QD10BFF and QD10AFF magnets with a half aperture of 8 mm. From Fig.4 we can also see that the beam halo distribution is asymmetric. This asymmetric distribution could be correlated to the position of TBP. In order to investigate this correlation we performed a series of measurements moving the TBP vertically. Fig.5 shows the beam halo distribution corresponding to different TBP positions (top), the change of background level observed when moving the TBP is consistent with the post-IP background monitor measurements (bottom).

The source of the observed asymmetry has to be investigated by doing more systematic measurements using the wire scanners or the diamond detector in a future. In this case a dedicated collimation system with the possibility of collimating the two sides of the beam halo at the same time can be useful.

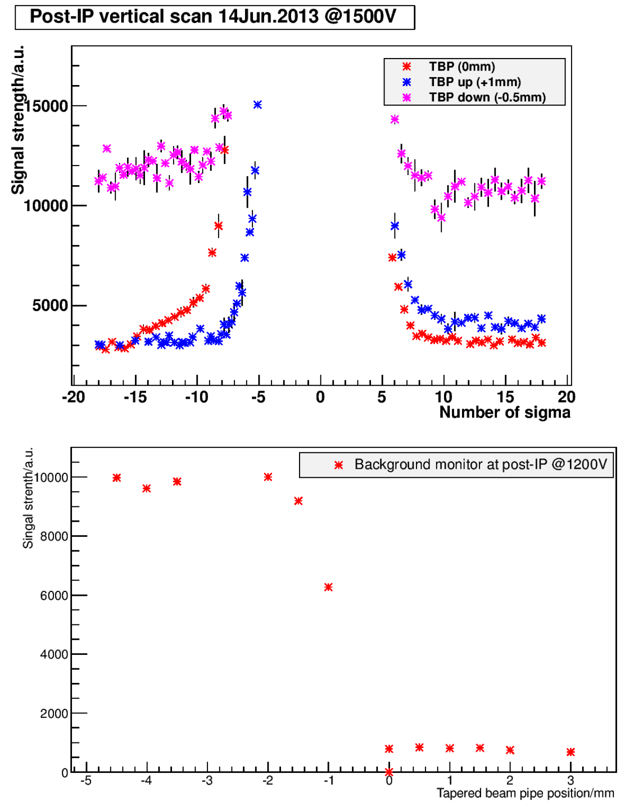

Figure 5: Beam halo distribution (top) and background level (bottom) at different TBP position.

CONCLUSION AND FUTURE PERSPECTIVE

Halo measurements in the EXT line were done using MW2X, MW3X and the post-IP wire scanner. Halo density parameterization for measurements in the EXT line wire scanners was done for the present beam line and compared with the old model. Although the measurements were done with different voltages and the data was combined, we could not get sufficient dynamic range to see the halo distribution beyond 6σ due to the large photon background. Therefore a new instrument is required to measure the beam halo distribution. A diamond detector has been developed and will be implemented at ATF2 in the end of 2014 for this purpose [7]. A post-IP asymmetric beam halo distribution was observed. More studies need to be carried out to understand the source of the asymmetric halo distribution and the correlation between halo distribution in the EXT line and at post-IP. A dedicated beam halo collimation system is being designed to control the background for the beam halo measurement using diamond detector at post-IP.

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